MAR 0 4 1986

AEDC-TR-85-50

C.3

Empirical Development of Ground Acceleration, Velocity, and Displacement for Accidental Explosions at J5 or the Proposed Large Altitude Rocket Cell at Arnold Engineering Development Center

Barbara C. Davis
Lawrence Livermore National Laboratory
University of California
Livermore, CA 94550

PROPERTY OF U.S. AIR FORCE
AEDC TECHNICAL LIBRARY

TECHNICAL REPORTS
FILE COPY

December 1985

Final Report for Period October 1983 – September 1984

Approved for public release; distribution unlimited.

ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENNESSEE
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

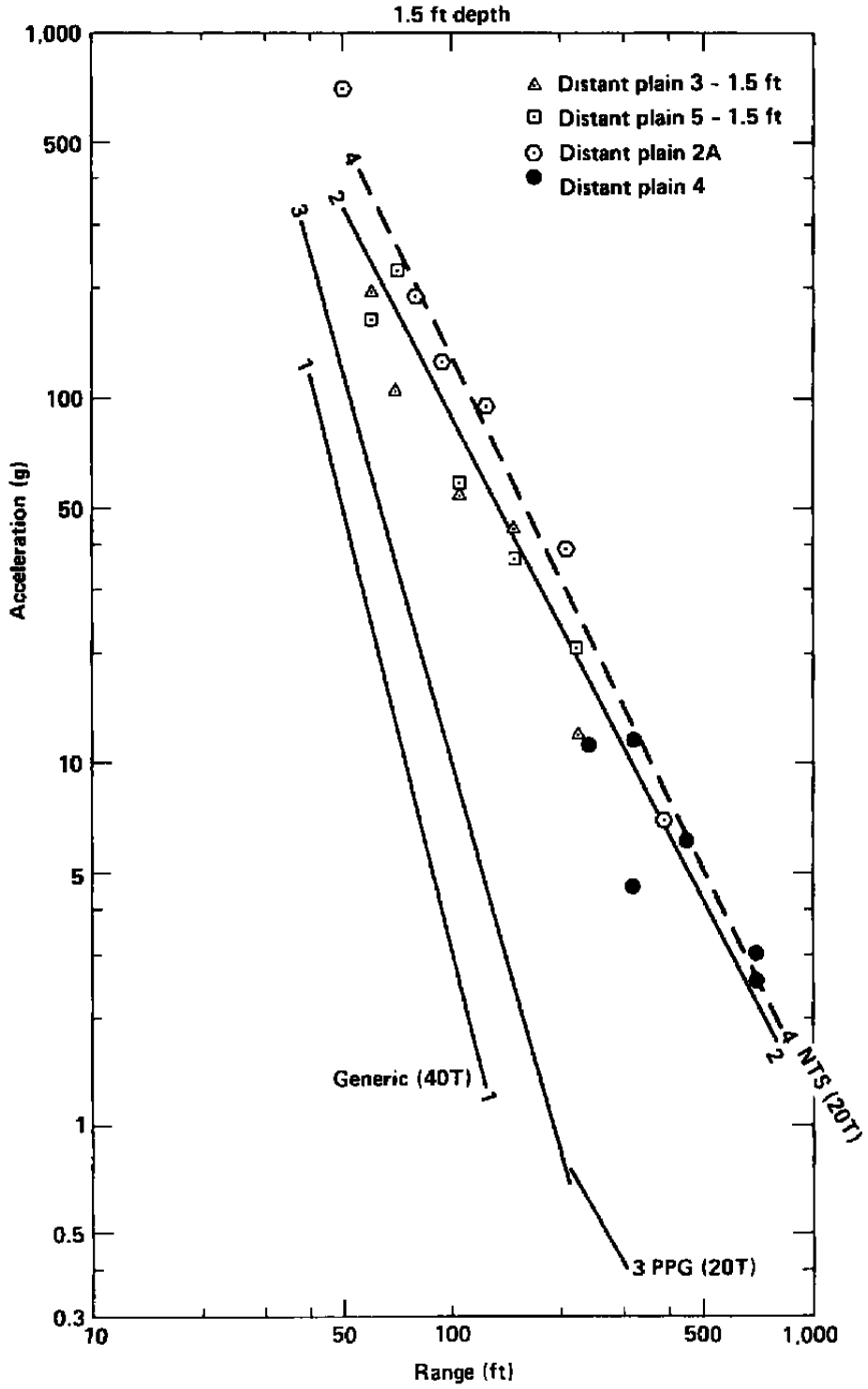

Figure 8. Near-surface peak vertical acceleration for surface and surface-tangent 20T high explosive events at wet, layered sites: Generic w/2.0 yield weighting [1], Least-squares regression [2], Sauer and Schoutens PPG [3], Sauer and Schoutens NTS [4] peak vertical acceleration relationships.

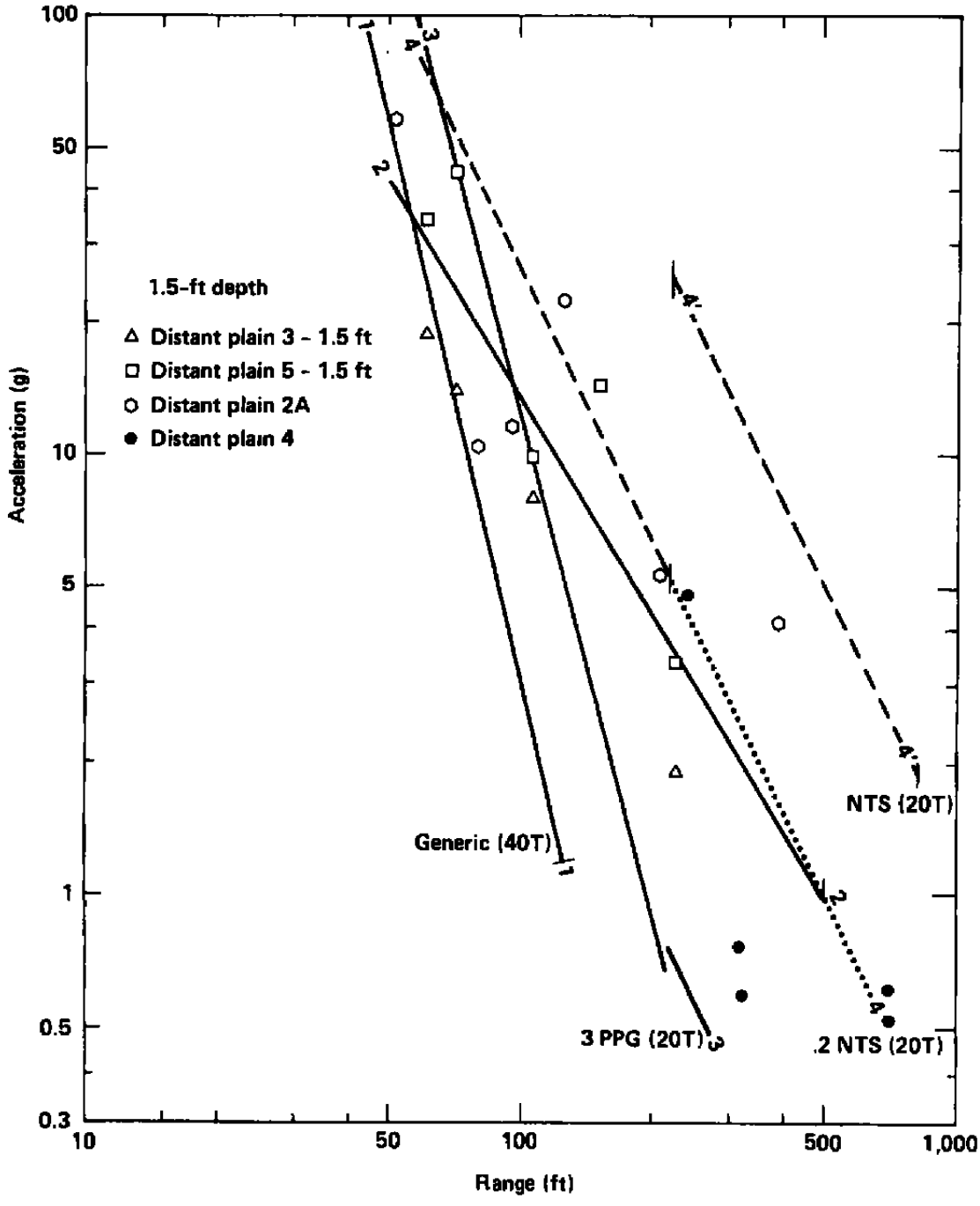

Figure 9. Near-surface peak horizontal acceleration for surface and surface-tangent 20T high explosive events at wet, layered sites: Generic w/2.0 yield weighting [1], Least-squares regression [2], Sauer and Schoutens PPG [3], Sauer and Schoutens NTS [4] peak horizontal acceleration relationships.

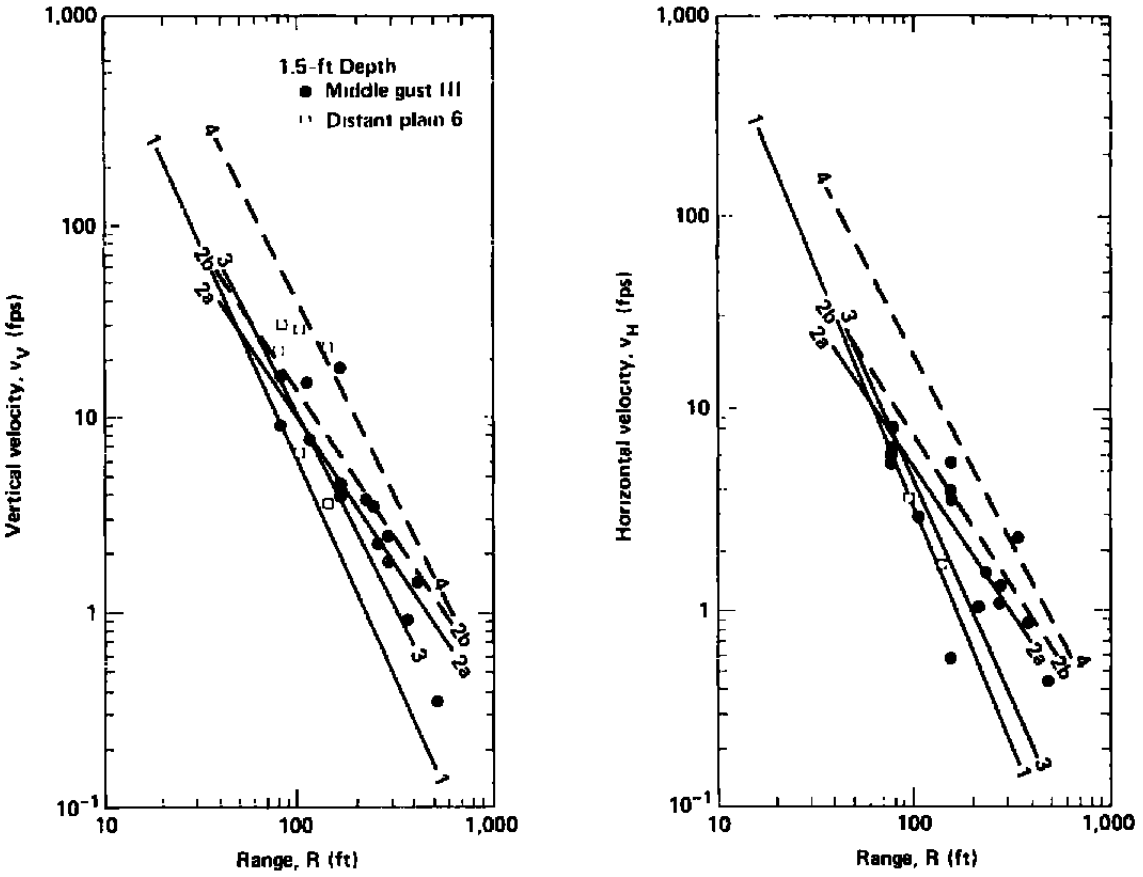

Figure 10. Near-surface peak velocity for surface tangent 100T high explosive events at wet, layered sites: Sauer HE [1], Generic Ground Roll [2a], Generic Ground Roll w/2.0 yield weighting [2b], Sauer PPG [3], Sauer NTS [4] peak velocity relationships.

Displacement Comparisons

Displacement data available are derived from integrated velocity time histories. The displacement data are shown in Figs. 12 and 13. Data from varying size events are plotted together, with yield used to weight the range and displacement. Least-squares regression analyses generate the following relationships:

$$d_{v\max}/W^{1/3} = 2.4 \times 10^{5}(R/W^{1/3})^{-3}, \qquad (10)$$

$$d_{h\max}/W^{1/3} = 5 \times 10^{7}(R/W^{1/3})^{-2.65}, \qquad (11)$$

where $d_{v\max}$ and $d_{h\max}$ are in inches, W is in kilotons, and R is in feet. The Sauer and Schoutens PPG displacement relationship [Eq. (7)] is plotted (curve 2) in Figs. 12 and 13; their relationship falls considerably below the data. The generic site relationship is not plotted as it is not compatible with yield weighting. A comparison of the value predicted by the generic site relationship with the data shows that the generic relationship predicts vastly below the data.

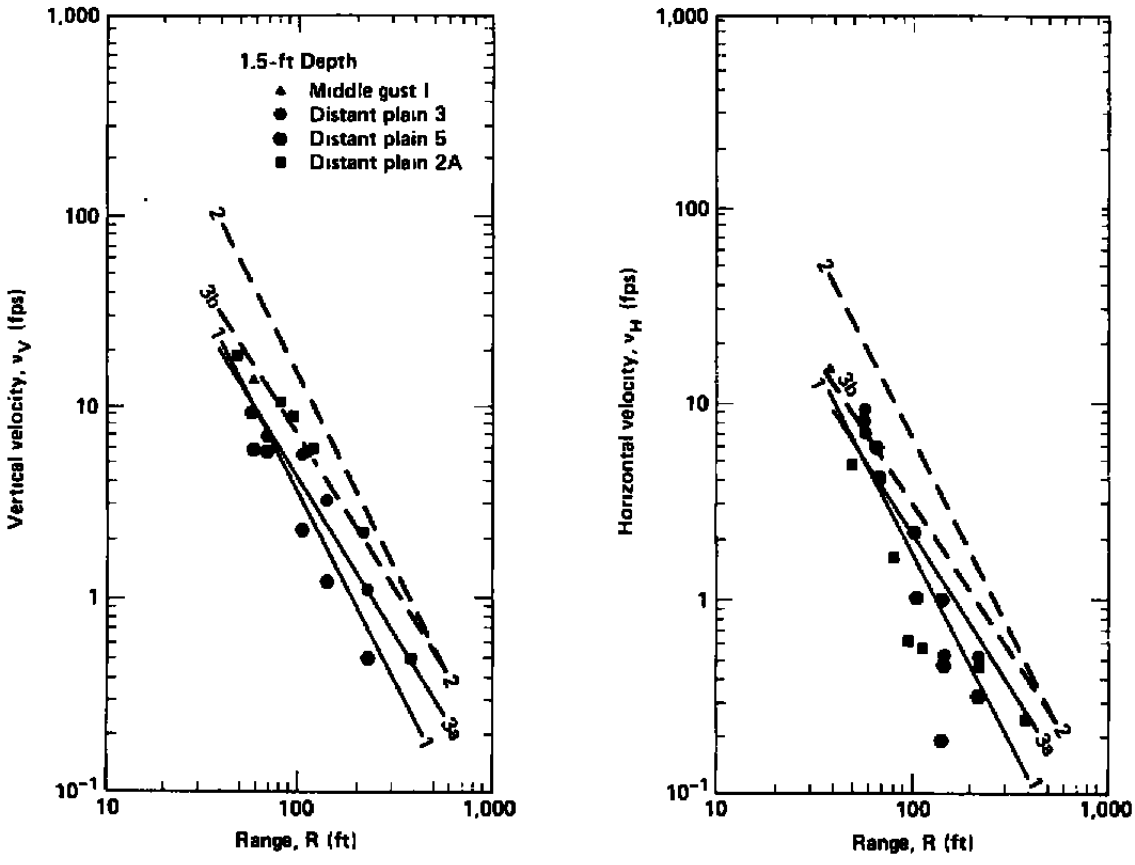

Figure 11. Near-surface peak velocity for surface and surface-tangent 20T high explosive events at wet, layered sites: Sauer PPG [1], Sauer NTS [2], Generic Ground Roll [3a], Generic Ground Roll w/2.0 yield weighting [3b] peak velocity relationships.

The vertical and horizontal displacements derived from the integrated velocity time histories are so similar in magnitude that a single relationship is developed to predict ground displacements at AEDC. That relationship is:

$$d_{max}/W^{1/3} = 1 \times 10^{K}(R/W^{1/3})^{-2.8}, \qquad (12)$$

where d_{max} is in inches, W is in kilotons, and R is in feet.

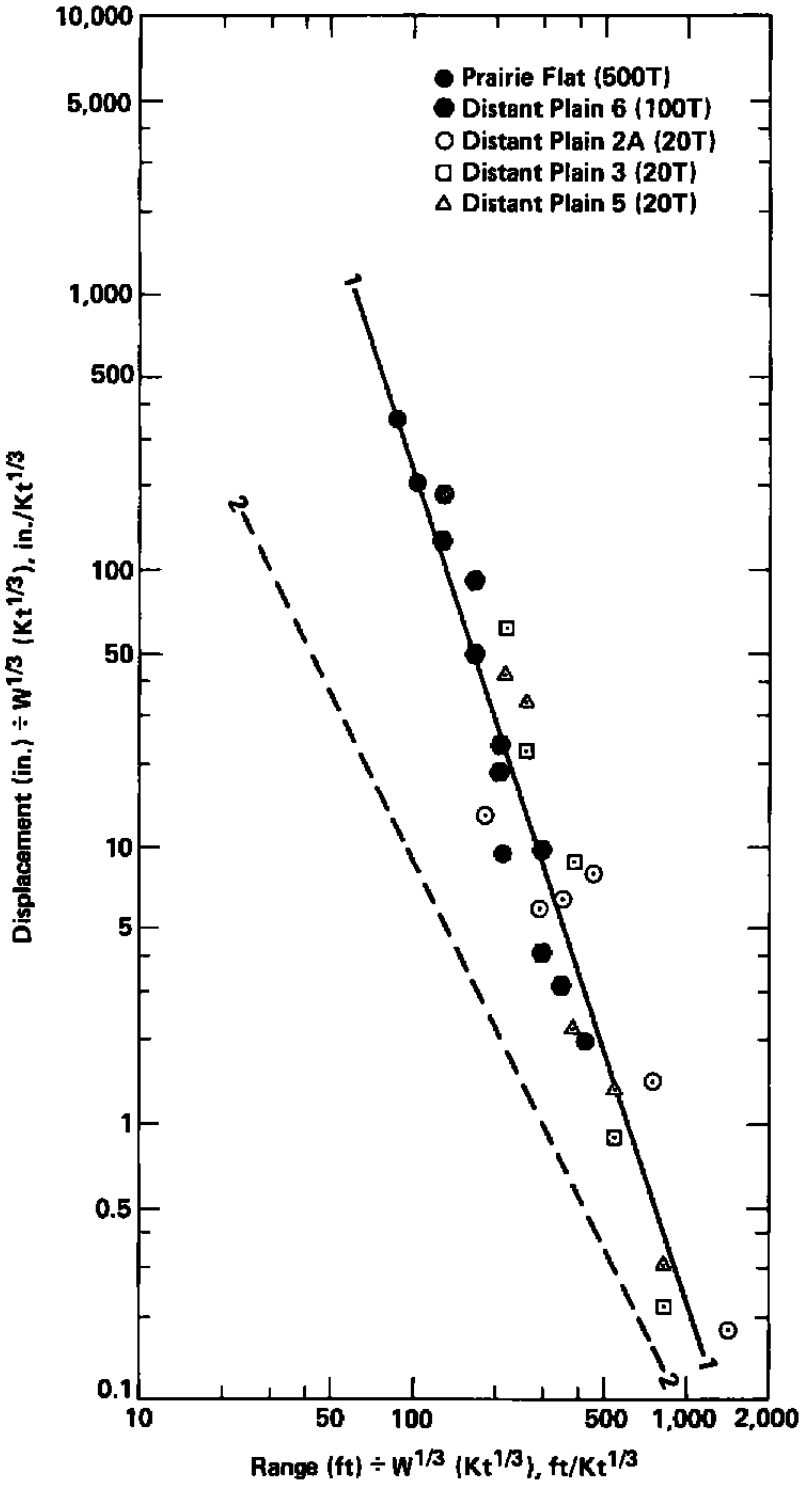

Figure 12. Near-surface peak vertical displacement for high explosive events at wet, layered sites: Least-squares regression [1], Sauer and Schoutens PPG [2].

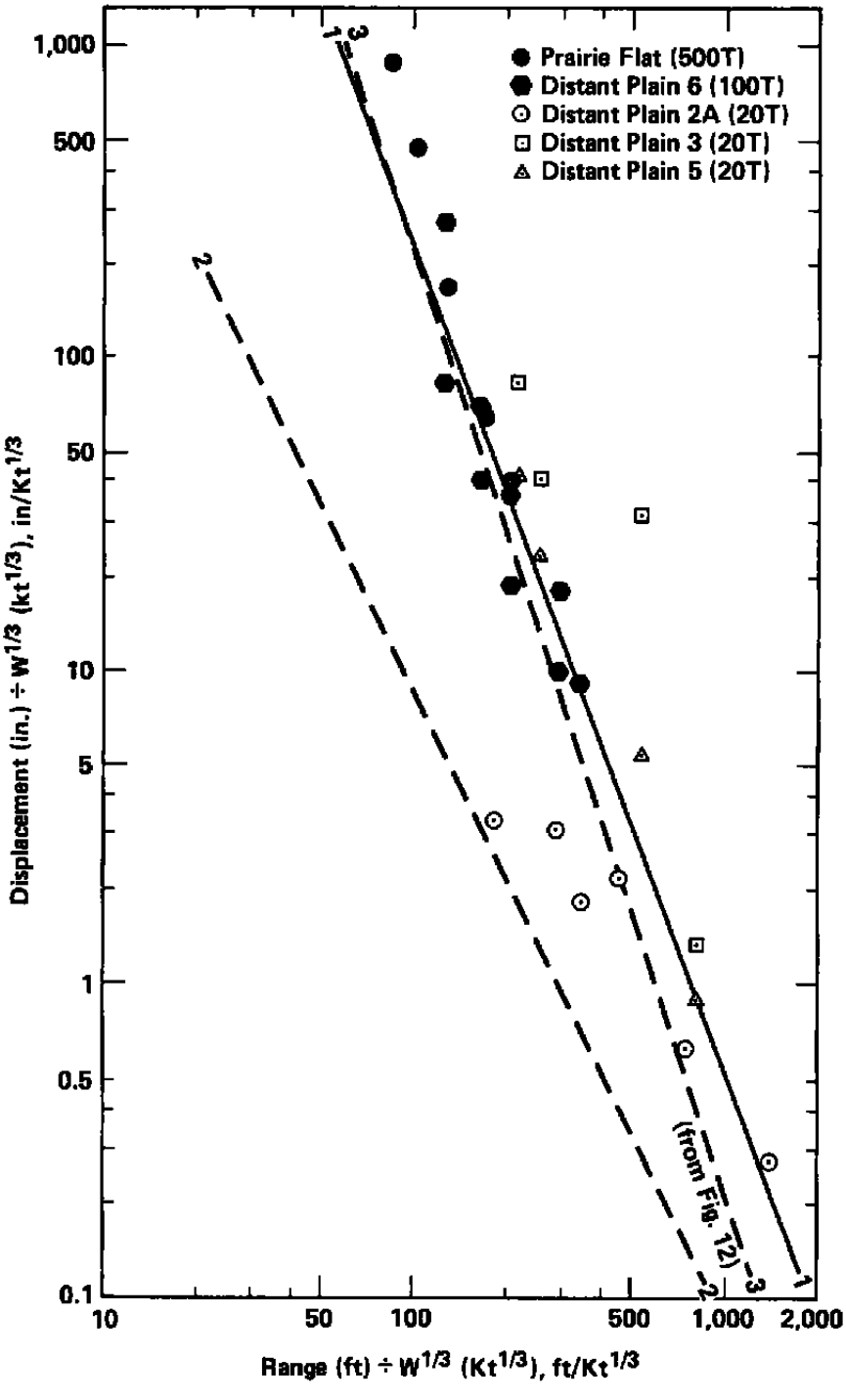

Figure 13. Near-surface peak horizontal displacement for high explosive events at wet, layered sites: Least-squares regression [1], Sauer and Schoutens PPG [2], Least-squares regression for vertical displacements [3].

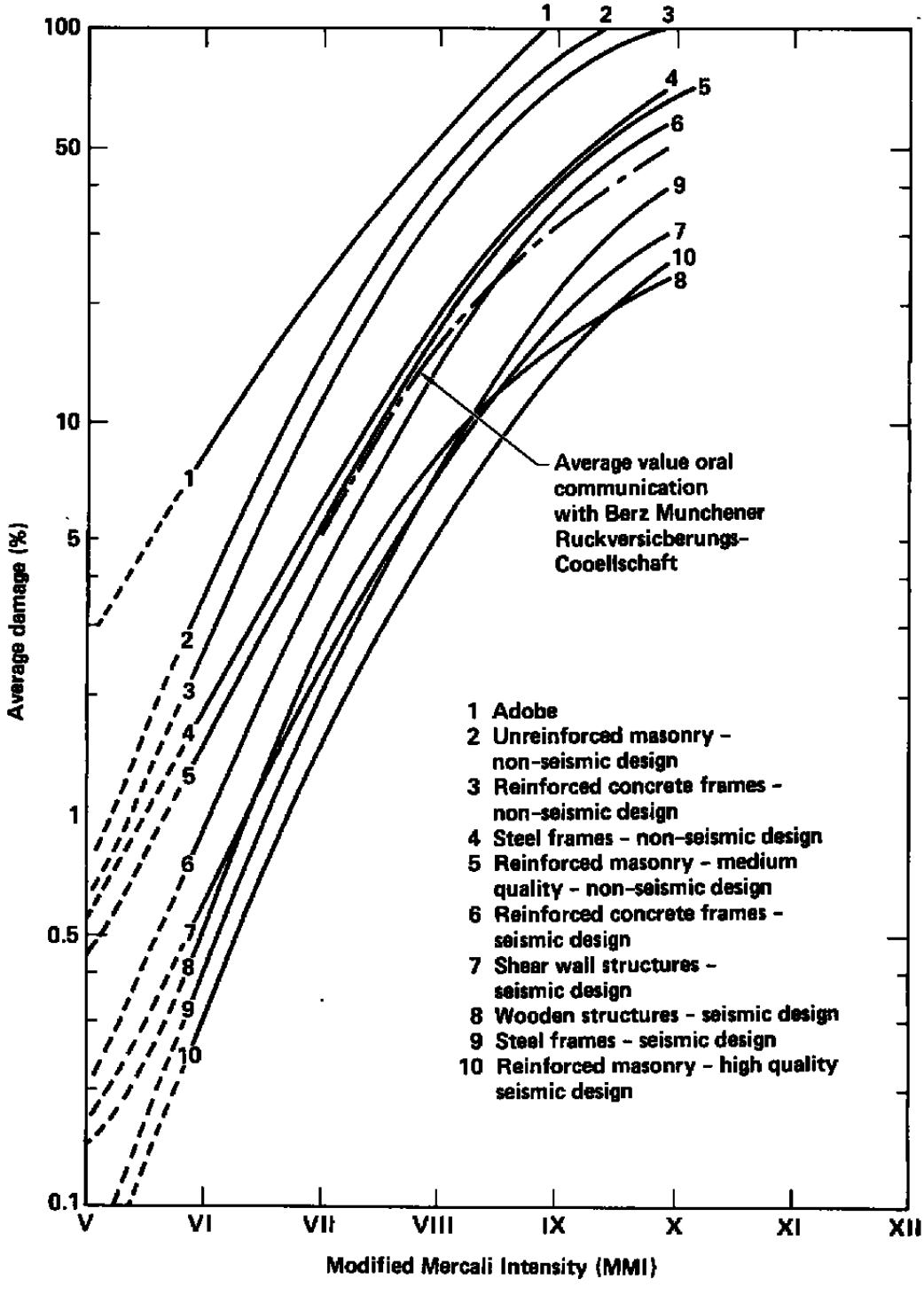

Figure 22. Average damage versus intensity (MMI) for ten construction types.[9]

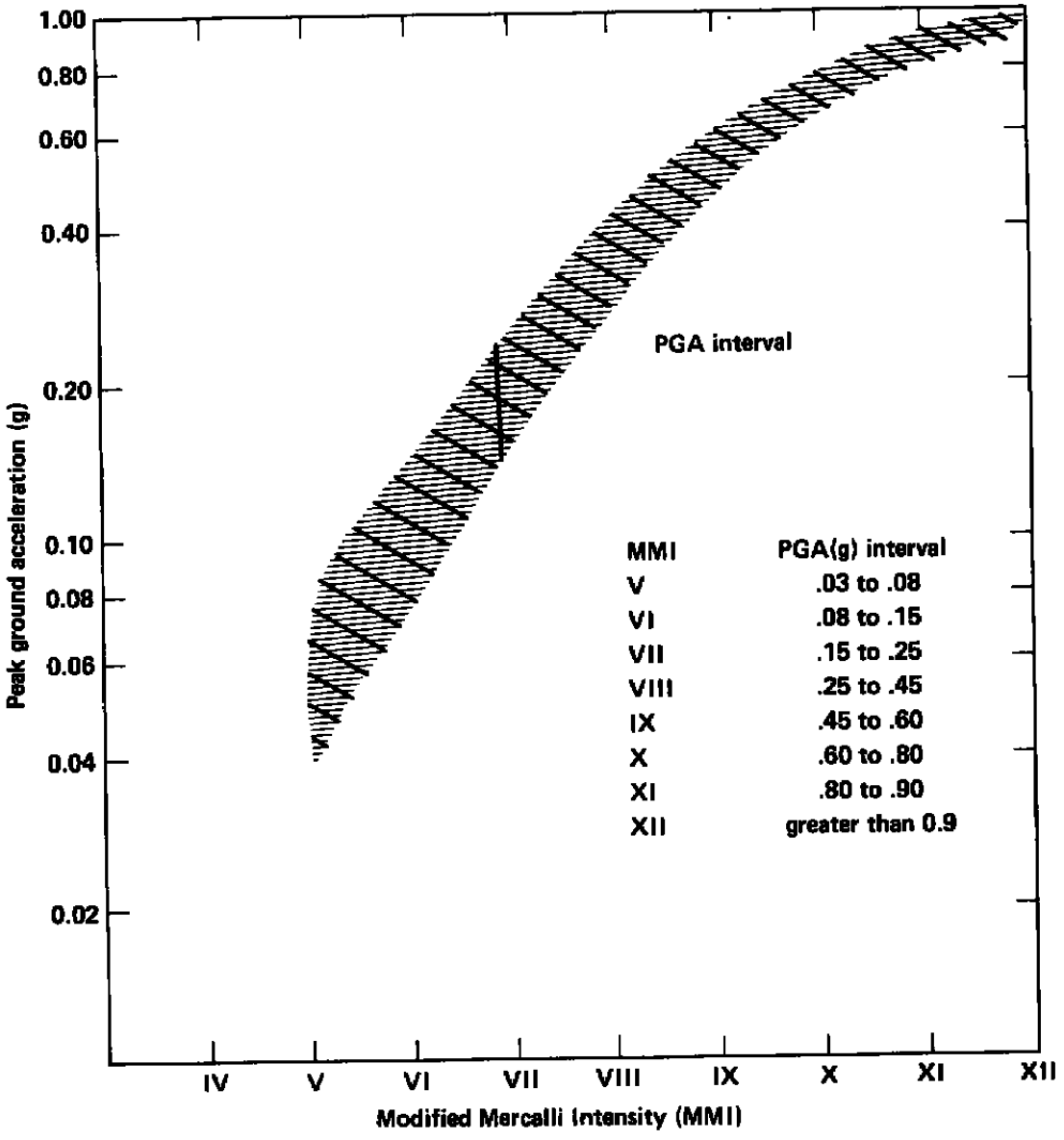

Figure 23. Modified Mercalli Intensity (MMI) relationship to peak ground acceleration.[9]

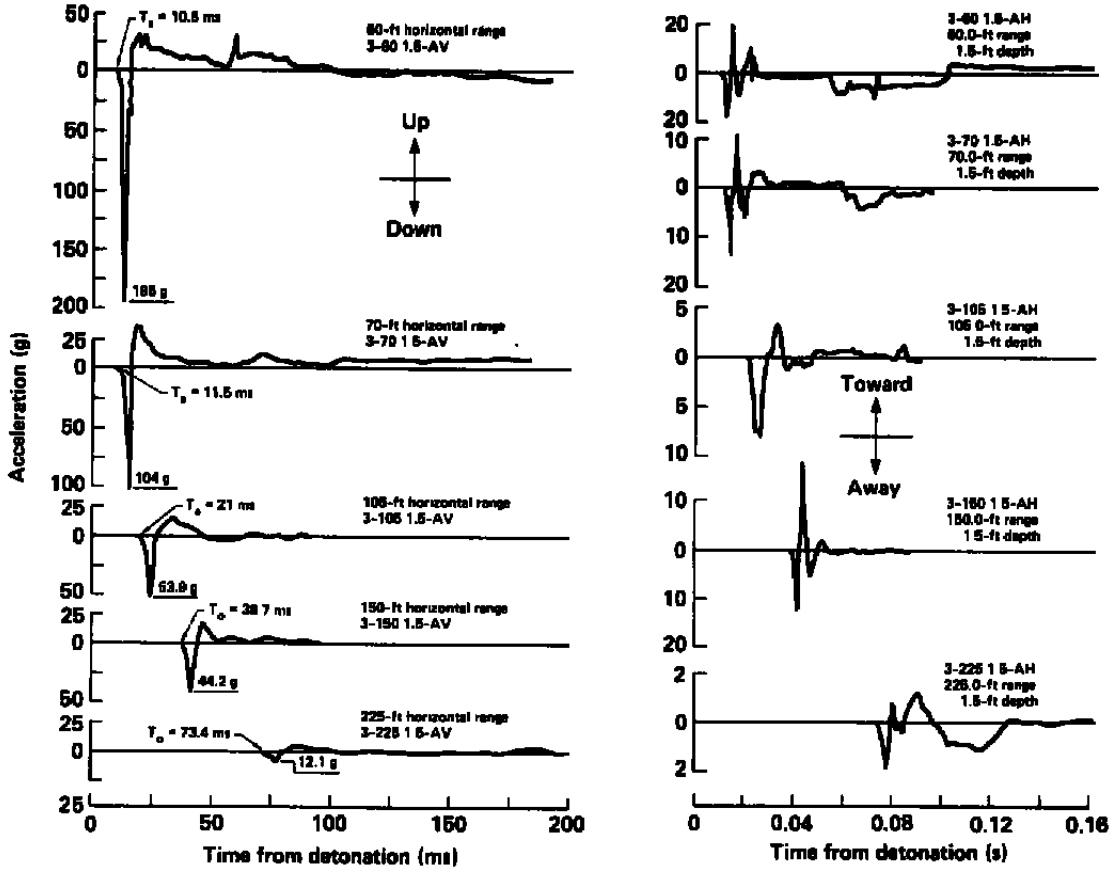

Figure 24. Accelerations, DISTANT PLAIN 3 (20T TNT equivalent surface blast).

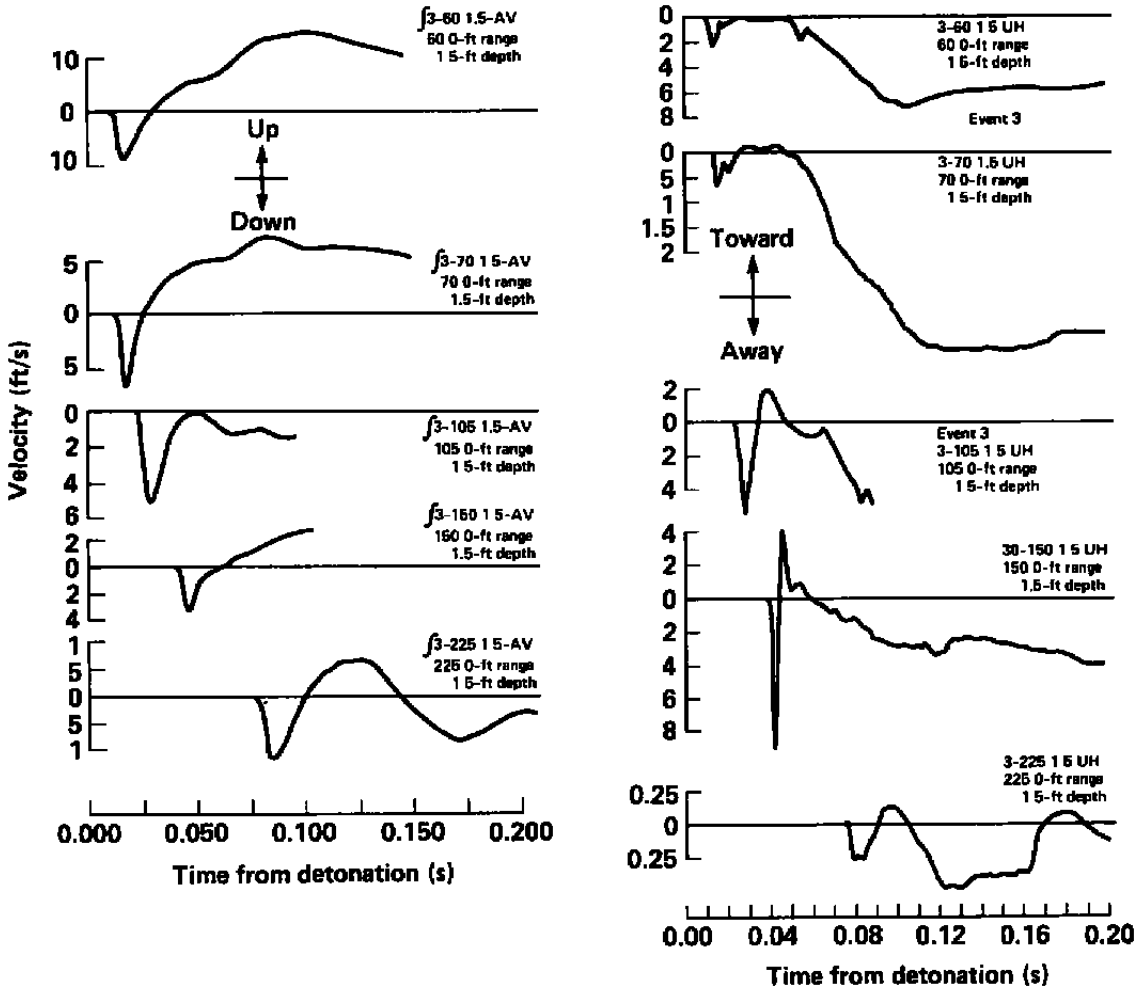

Figure 25. Velocities, DISTANT PLAIN 3 (20T TNT equivalent surface blast).

References

1. C. Tirres and F. D. Cantrell, *A Proposed Large Solid Rocket Test Cell*, AIAA-84-0606, prepared for the AIAA 13th Aerodynamic Testing Conference, San Diego, CA (March 5–7, 1984).
2. R. E. Crawford, C. J. Higgins, and E. H. Baltmann, *The Air Force Manual for Design and Analysis of Hardened Structures*, Air Force Weapons Laboratory, Kirtland AFB, NM, AFWL-TR-74-102 (1974).
3. F. M. Sauer and J. E. Schoutens, "Volume IV, Part I—Empirical Analysis of Ground Motion from Above and Underground Explosions," *Nuclear Geoplosics Sourcebook*, DNA 6501H-4-1 (1979).
4. R. F. Flint and B. J. Skinner, *Physical Geology* (John Wiley & Sons, New York, 1977), 2nd ed., pp. 390–406.
5. SwRI, *A Manual for the Prediction of Blast and Fragment Loadings on Structures*, Southwest Research Institute, DOE/TIC-11268 (1980).
6. N. Lipner, D. C. Anderson, and P. K. Dai, *Ground Motion Environments for Generic Site Conditions*, TRW Systems Group, DNA 3872F (1975).
7. N. M. Newmark and J. D. Haltiwanger, *Air Force Design Manual—Principles and Practice for Design of Hardened Structures*, Air Force Special Weapons Center, Kirtland AFB, NM, AFSWC-TDR-62-138 (1962).
8. F. M. Sauer, *Summary Report on DISTANT PLAIN Events 6 and 1a Ground Motion Experiments*, Stanford Research Institute, Menlo Park, CA, DASA-2587 (1970).
9. H. C. Shah, Purdue University, West Lafayette, IN, Class Notes for Earthquake Engineering and Seismic Hazard Analysis—CE 687 (Fall Semester 1981).
10. W. I. Duvall and D. E. Fogelson, *Review of Criteria for Estimating Damage to Residences from Blasting Vibrations*, U.S. Department of the Interior, Washington, DC, U.S. Bureau of Mines Report of Investigations 5968 (1962).
11. A. T. Edwards and T. D. Northwood, "Experimental Studies of the Effects of Blasting on Structures," *The Engineer*, v. 210 (September 30, 1960).
12. M. D. Trifunac and A. G. Brady, "On the correlation of seismic intensity scales with the peaks of recorded strong ground motion," *Bull. Seismol. Soc. Am.* **65** (1975).
13. SMA, *Design and Evaluation Criteria for Potential Motor Detonations at the Arnold Engineering Development Center* (DRAFT), Structural Mechanics Associates, Newport Beach, CA, NTS/SMA 12211.03 (1984).

Bibliography

Bollinger, G. A. (1980), *Blast Vibration Analysis*, Southern Illinois University Press, Carbondale and Edwardsville, IL.

Ferritto, J. M., and J. B. Forrest (1975), *Ground Motions From Pacific Cratering Experiments 1000-Pound Explosive Shots*, TR-808, Civil Engineering Laboratory, Port Hueneme, CA.

Hendron, A. J., Jr. (1975), "Engineering of Rock Blasting on Civil Projects," *Structural and Geotechnical Mechanics*, Prentice-Hall, pp. 242–277.

Hendron, A. J., and C. H. Dowding (1974), "Ground and Structural Response Due to Blasting," *Advances in Rock Mechanics—Volume II, Part B*, Proceedings of the Third Congress of the International Society of Rock Mechanics, Denver, CO.

Ingram, J. K. (1971), *Operation DISTANT PLAIN, Events 1, 2A, 3, 4, and 5; Project 3.02a, Earth Motion and Stress Measurements*, TR-N-71-3, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

Jaramillo, E. E., and R. E. Pozega (1974), *MIDDLE GUST Free Field Data Analysis*, AFWL-TR-73-251, Air Force Weapons Laboratory, Kirtland AFB, NM.

Langefors, U., and B. Kihlstron (1978), *The Modern Technique of Rock Blasting*, Third Edition, Halsted Press, John Wiley & Sons, New York, NY.

Naar, J. (1964), "Part One—Theory of Directly-Induced Ground Motion," *Nuclear Geoplosics*, DASA-1285(1), Defense Atomic Support Agency, Washington, DC.